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The Evolution of Total Ankle Arthroplasty

Bilal Jamal*, Mansur Halai, Anand Pillai
Earlspark Avenue, Newlands, Glasgow, United Kingdom

Abstract

Ankle arthritis can lead to disabling pain and loss of function. While arthrodesis surgery leads to reliable pain relief, it is associated with development of degenerative joint disease in adjacent joints. The success of hip and knee arthroplasty has led to interest in developing a total ankle arthropalsty. Unfortunately, this has, historically, been associated with poor results. This is due to a failure to appreciate joint biomechanics and optimial fixation techniques.

In this article, we describe the evolution in design of ankle arthoplasty. We comment upon differing generations of designs and introduce the reader to differing outcomes between these implants.

Keywords: Arthroplasty; Tibiofibular joint; Arthrodesis surgery

Introduction

Total hip and knee arthroplasty, while occasionally associated with poor results [1], are considered to be successful in abolishing pain and are associated with impressive function and survivorship [2,3]. Following such success, there was a move in the 1970s to develop an arthroplasty system for the ankle. It was hoped that ankle arthroplasty would allow for pain relief, retention of tibiotalar joint motion and improved function. Unfortunately, a failure to appreciate the biomechanics of the ankle joint coupled with the typically young age of patients presenting with ankle arthritis led to early failure of the prosthesis. There has been a requirement for numerous iterations of arthroplasty designs with variations in degree of constraint, number of components and methods used to achieve fixation. A greater understanding of soft tissue handling and the role of deformity correction in other parts of the foot has led to improved survivorship.

In this article, we aim to review ankle arthroplasty, paying particular attention to the anatomy of the ankle joint, the relevant biomechanics and the evolution of arthroplasty design.

Anatomy

The reader will be well acquainted with the anatomy of the ankle joint. The distal tibia and its malleolus along with the lateral malleolus form the ankle mortise which articulates with the talus. The talus is wider anteriorly than posteriorly. In addition to the ankle joint, the distal tibia and fibula articulate to form the distal tibiofibular joint.

The ankle joint is highly congruent which provides inherent stability. The ankle capsule also provides some stability as does the surrounding ligamentous complex. Laterally, there are 3 ligaments with the posterior most being strongest and the anterior most being most liable to injury. The three ligaments laterally are termed the anterior talofibular ligament, the calcaneofibular ligament and the posterior tibiofibular ligament. Medial ligamentous stability is provided by the deltoid ligament which has a superficial and deep component. The distal tibiofibular joint is stabilised by the anterior and posterior tibiofibular ligaments, the interosseous tibiofibular ligament and the inerosseous membrane.

In the normal ankle, an average of 15.3o of dorsiflexion and 39.7o of plantarflexion is attainable [4,5]. A small amount of motion occurs at the distal tibiofibular joint with the intermalleolar distance increasing by 1 mm from full plantarflexion to full dorsiflexion [6].

Biomechanics

Motion at the ankle occurs in three planes. Plantarflexion and dorsiflexion is the most important of these but motion also occurs within a transverse plane and a coronal plane. There are differing medial and lateral talar curvatures such that the ankle rotates in differing axes depending upon the position of the ankle in the saggital plane. With increasing plantarflexion of the ankle, the foot sits in external rotation. Dorsiflexion results in internal rotation. The weight bearing zone of the ankle has been reported to be 10 cm2 but is noted to accept 5 times body weight during gait [7].

Evolution of Design

Ankle arthroplasty surgery was first performed in 1913 by Eloesser [8]. He described cartilage allograft transplantation. Total ankle arthroplasty, characterised by resurfacing of both the talar and tibial articular surface, was not described in the literature until 1973. Lord and Marotte excised the talus and inserted an acetabular cup into the calcaneus with a femoral stem inserted into the distal tiba [9,10]. This surgery was performed in 25 patients. In only 7 patients was such surgery considered satisfactory with failure of surgery noted in 12 cases. The authors recommended discontinuing use of the prosthesis and recommended arthrodesis surgery for ankle arthritis.

Ankle arthrodesis is associated with a high rate of fusion with Maurer reporting 100% fusion rates using transarticular crossed screw compression [11]. They noted a lower rate of fusion with charnley compression arthrodesis. It leads to good post operative function [12] but is in the long term associated with arthritic changes within the ipsilateral foot [13]. In the unshod foot, ankle arthrodesis is also associated with slowed velocity of gait and shortened length of stride [12].

A desire to overcome these problems led to the continuing development of what came to be known as first generation ankle arthroplasties. The fact that there were over 20 different implants introduced over the period of one decade gives some indication as to the overall success of any one implant. Universally, these were two

***Corresponding author:** Bilal Jamal, 88 Earlspark Avenue, Newlands, Glasgow, G43 2HD, United Kingdom Tel: +447584169123; E-mail: bjamal@doctors.org.uk

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component designs with cement fixation. They were divided into those implants which were constrained and those that were unconstrained.

Unconstrained ankle prostheses, such as the Newton replacement, included a vitallium talar implant with a high density polyethylene tibial component. Newton reported his results in 1982 and noted 50% survivorship at a mean follow up of 3.4 years in 50 patients [14]. Evanski also reported the early results of an unconstrained prosthesis, the Irvine ankle replacement, follow up was for a mean of 0.75 years only [15]. Even at such short follow up, they noted only 93% survivorship with one patient requiring fusion and another requiring below knee amputation. Wound complications were noted in three patients. The poor survivorship in unconstrained ankle replacements led to a rapid decline in their implantation.

The early results of constrained ankle replacements were encouraging with Stauffer following up 102 patients for an average of 1.9 years after implantation of the Mayo ankle replacement, a highly constrained two component design with a polyethylene tibial component. 93% survivorship was demonstrated [16]. Longer term review was less impressive. Kitaoka and Patzer reviewed the long term results of the mayo ankle replacement and noted acceptable survivorship of 79% at 5 years but worryingly poor survivorship at 15 years of 61% [17]. Revision surgery was needed in 41% of patients for ongoing pain. The authors concluded that they could not recommend the mayo ankle replacement for rheumatoid arthritis or osteoarthritis of the ankle. Unfortunately, other constrained first generation ankle prostheses had poorer long term outcome figures. The conaxial ankle replacement had, at a mean of 10.8 years follow up, a 90% incidence of implant loosening. It was also associated with early fractures of the malleoli in 22% of patients with 14% of patients complaining of impingement symptoms [18]. Again the message from the authors was that this prosthesis should not be implanted. Similar messages came from other authors [19].

Reasons posited for early failure of first generation implants include poor resistance to wear and deformation from high local stresses in unconstrained Implants [20]. The large degree of bone resection required for cement fixation is also implicated in early failure. Hvid noted that trabecular bone strength at the ankle joint decreased significantly with increasing thickness of resection [21]. They postulated that the resection surfaces needed were too weak to support the loads imposed on them by ankle arthroplasty designs. A failure to appreciate the degree of pre-operative ankle and hindfoot deformity that could accept an ankle replacement will have had implications for wear and loosening. Inevitably, poor surgical technique associated with a surgical learning curve and poor instrumentation will also have influenced post operative function and survivorship.

The professor of orthopaedics from the Western Infirmary, Glasgow stated in an editorial in the Journal of Bone and Joint Surgery that with the techniques available at that point, in 1985, that arthroplasty could not be recommended. He suggested that prior to considering arthroplasty surgery, there had to be improvements in prosthetic design, uncemented implants had to be routinely available and improved surgical technique was required.

Second generation ankle replacements addressed these concerns. Universally, these are uncemented prostheses with minimal bone resections. They are semi constrained and allow for improved joint kinematics. These prostheses can be divided into two component and three component designs. The three most common second generation ankle replacements commercially available are the Low Contact Stress (LCS), the Agility and the Scandanavian Total Ankle Replacement (STAR).

Of the fixed bearing ankle replacements, the Agility Ankle replacement has the longest follow up having been first introduced in 1984 [22,23] and is the most popular prosthesis in the United States. The LCS, or Buechel – Pappas prosthesis can be divided into mark 1 and mark 2 implants. At 20 years, there is 74% survival for the mark 1 prosthesis and at 12 years there is 92% survivorship for the mark 2 prosthesis [24]. The mark 2 component is characterised by two talar fins and a deeper meniscal component. The STAR is the most popular prosthesis in Europe. In its first iteration, this was a cemented, two component design which has subsequently evolved into a cementless, three component design. The mean 10 year survivorship with this implant is 70.7% [25]. At 14 years, however, survivorship is less than 50%.

With a further understanding of modes of failure, third generation ankle replacements have been developed. The commercially popular ones include the Salto (Tornier), Mobility (DePuy) and HINTEGRA (Newdeal). These are all three component designs which pay increased attention to ligamentous balancing as well as allowing for salvage options in the failed arthroplasty. Overall, while these prostheses show promise with satisfactory mid term results, there is a lack of long term outcome data on outcomes. This must be addressed prior to their wider uptake. There must also be further results from non inventor units prior to widespread confidence being placed in these implants.

The Salto total ankle replacement is an uncemented implant which is titanium plasma sprayed. It has 2 radii of curvature which are theorised to avoid injury to the deltoid ligament. A fixation plug into the tibia allows for better initial fixation. The prosthesis also allows for more physiologic motion within the ankle. It allows for external rotation with progressive dorsiflexion. Bonnin's group i.e. an inventor series have demonstrated implant survivorship of 98% at 68 months [26]. At a mean of 8.9 years follow up, Bonnin's group have demonstrated survivorship of 65% if any revision surgery is considered but this rises to 85% if revision of any component is considered [27]. When evaluated by an independent group at a mean of 5 years, an average survivorship of 86.6% was noted. In certain groups, such as the rheumatoid population, the results were even more impressive [28].

The mobility ankle replacement has been designed with a porous coating to allow for bone ingrowth along an uncemented implant. A conical tibial stem aids in initial stability. Fins on the undersurface of the talar component also aid in initial stability. The designers have been conscious of the need to keep bone resection to a minimum. Wood, one of three senior clinical designers, has reported his initial results. Four year survival of the implant was 93.6% [29]. An independent group has at a mean of four years follow up noted a 94.4% surviroship. However, they noted although more than 85% of patients are satisfied, there is a high incidence of persistent medial gutter pain [30,31].

The HINTEGRA ankle replacement has a tibial component which can achieve supplemental fixation with 2 screws. It is only 4mm thick. The talar component has 2 radii of curvature with rims medially and laterally to guide translation of the meniscus. An inventor series with an impressive number of cases (722) documented 84% survivorship at 10 years. This is very much a satisfactory result within ankle arthroplasty surgery. However, there is a distinct lack of outcomes data from non inventor units. This must be addressed in future research.

Conclusion

Ankle replacements have historically demonstrated poor results. This has been due to a poor understanding of ankle joint kinematics. An improved understanding of biomechanics, fixation methods and soft tissue handling as well as a greater appreciation of deformity correction have all contributed to improved long term outcomes from ankle replacement surgery. This article has reviewed the current literature so as to introduce the reader to the evolution of design in ankle arthroplasty. This is with the aim of leaving the reader in a better position to critically appraise new innovations in ankle arthroplasty design.

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